

Appendix 5: Considerations on restoration of the long-spined sea urchin, *Diadema antillarum* to the reefs of Florida Keys.

It is well documented in the scientific literature that the unprecedented, almost complete mortality of the long-spined sea urchin, *Diadema antillarum*, in the pandemic that afflicted this species in 1983-4, has had a disastrous effect on coral reefs of the Caribbean, Gulf of Mexico, Florida, and the Bahamas. Loss of this keystone herbivore has shifted the ecology of coral reefs from stony corals to dominance of macro algae and algal turf. Natural recovery of small pockets of *Diadema* populations in Jamaica, Belize, Dry Tortugas and other areas, and our project, and others, on artificial restoration of long-spined sea urchins has shown that when adequate populations of *Diadema* are restored to coral reef areas, this trend is reversed and coral settlement and growth once again become dominant on the reef. It is obvious that the restoration of *Diadema* to the coral reefs of the Florida Keys would be immeasurably beneficial to the ecology of the coral reefs and to the future economy of the Keys and all of South Florida.

Initially, in the first years after the plague, it was generally anticipated that *Diadema* populations would recover, seeded from less affected areas in the southern Lesser Antilles and from small pockets of *Diadema* that managed to survive this plague. Extensive repopulation has not occurred, however, in the 20 years since this mortality.

Larval distribution and place of settlement of post-larval *Diadema* depends on the vagaries of oceanic currents and the interaction of oceanic and near shore water masses. Late stage larvae just before settlement may be broadly dispersed over great areas or concentrated in bands of plankton, and both of these conditions probably occur at various times over Florida reefs. Delivery of late larvae by favorable currents over a proper substrate will result in a population of juvenile *Diadema*. Post-larval *Diadema* do not settle and/or do not survive well in reef areas where algal growth on the rocky substrates is not removed by the scouring effects of wave action or by the activity of adult *Diadema*. A rocky reef surface cleared of most algal growth is apparently critical for post larval settlement of urchins (and corals).

Predation on juvenile and adult urchins is extensive and when favorable conditions of larval production and distribution do result in successful settlement, predation quickly begins to reduce their numbers. Despite the great fecundity of this species, the reproductive potential of the restricted, small populations of *Diadema* that do exist is not great enough to generate the incredibly vast numbers of larvae necessary to successfully create persistent pioneer populations on algae dominated coral reefs, or provide the number of recruits necessary to maintain and expand the small populations that do become established. Thus the lack of continuous settlement and survival apparently restricts successful colonization to areas with a low incidence of predation, and few of these *Diadema* survive to become large adults.

It is possible, however, that human effort can help restore this keystone herbivore to Florida Keys reefs. The immense fecundity of the adult female, 10 to 20 million eggs per spawn, is the key factor that can make the reproductive potential of numerous small, dense populations possibly great enough to enhance restoration of *Diadema* to the reefs.

It may be that in time *Diadema* will repopulate the reefs of the Keys naturally. It is also possible that, despite any efforts that we might employ to assist recovery, this species may never again attain densities that will curtail algal growth on the reefs.

There is the opinion that the area of the reefs is so extensive and whatever restorative efforts we might mount so puny, that we cannot change the future course of nature, whatever that might be. Also, there is the specter that the plague may return at any time and quickly wipe out years of work. This view holds that our funds, time, and efforts would be better spent monitoring the populations, better understanding the dynamics of coral reef ecology, and in managing our relationships with the reefs and marine resources in the best way possible under the existing natural conditions.

There is validity to this viewpoint, and this may well be the best way to deal with this situation. We are, however, reminded of that famous quote in 1883 by the great biologist Thomas Henry Huxley who said in his inaugural address to the Fisheries Exhibition in London in 1883:

“I believe, then, that the cod fishery, the herring fishery, the pilchard fishery, the mackerel fishery, and probably all the great sea fisheries, are inexhaustible; that is to say, that nothing we do seriously affects the number of the fish. And any attempt to regulate these fisheries seems consequently, from the nature of the case, to be useless.”

The argument that efforts to restore *Diadema* are not practical or feasible is a reversal of Huxley’s argument, but it has the same perspective; that given the immensity of nature, human efforts are doomed to failure. And this can be correct, and usually is where a strong economic advantage is not present. But as developments in the years since Huxley’s pronouncement so well illustrate, in this modern age it all depends on the intensity and breadth of human effort. Great effort can achieve great ends as well as great destruction. Although it is probably not wise at this point to invest many millions of dollars into efforts to restore *Diadema*, we feel that research and experimental effort into restoration of *Diadema* to the reefs of the Florida Keys is time, funds, and effort well spent.

In our opinion, there are two main pathways that should be followed that may aid restoration of *Diadema* to the reefs.

The first is the translocation of juvenile *Diadema* from areas where they are at high risk of mortality from storms and predation to small, complex reef areas. We have demonstrated that the act of translocation causes little, if any, direct mortality. Areas in the lower Keys may be best since larvae originating there may have the best chance of settlement on Keys reefs. However, populations should be established on Upper Keys reefs as well since eddy currents will distribute larvae southward as well as northward. Continuous translocation of urchins to these reef locations would substitute for natural recruitment and maintain the populations on these selected reefs at densities that will transform these small reef areas from algal to coral dominance and provide a density of urchins that can reproduce successfully. The efficacy of this tactic will depend on the numbers of reef areas that can be maintained in this manner, the more the better. These areas will not only produce large numbers of *Diadema* larvae, but also serve as research

areas for coral settlement and growth and, over time, perhaps as areas of high coral larvae production. Restoration and maintenance of *Diadema* on localized reef areas can be done with organized and directed volunteer effort and would entail relatively little expense. If successful, however, the benefit to the reefs from such projects could be enormous.

The second avenue is to work with hatchery techniques to produce larvae and juveniles from captive brood stock of adult *Diadema*. This process would be more costly but would have the advantage of controlled production with release in specific areas at specific times of large numbers of late larval and juvenile urchins. Tom Capo, Laboratory Manager of the Aplysia Resource Facility at the University of Miami, has already achieved hatchery production of juvenile *Diadema*. These laboratory reared *Diadema* have been released on Keys reefs in several experimental programs, but have not survived as well as wild collected juveniles. There are also difficulties in rearing larval *Diadema* past the final larval stages, through metamorphosis, and into the early juvenile stage. These difficulties, however, can be resolved through intensive research into rearing techniques with this species.

The two possibilities that hatchery production of *Diadema* present is the liberation of vast numbers of late larvae, near to metamorphosis into juveniles, at areas in the Keys favorable to settlement of post larval urchins. Depending on many factors, this may or may not be a viable technique for urchin restoration, but if a facility for hatchery production of juveniles is established, then release of excess late larvae should certainly be attempted and researched. The second possibility, hatchery production of large numbers of *Diadema* juveniles competent to survive on natural reefs would be greatly advantageous to restoration efforts. These juveniles, which could be produced in large numbers, could be used to establish new populations of *Diadema* on the reefs and/or used to provide recruits for maintenance of populations already established.

It would not be necessary initially to build a large and expensive hatchery for research and production of competent *Diadema* juveniles. Several hatchery facilities adequate for research into the techniques of hatchery propagation of *Diadema* currently exist in the Keys and at the University of Miami. New *Diadema* research programs may be able to use existing facilities and new research programs could be funded independently or through these existing facilities. Once the techniques for production of competent juveniles are refined and hatchery reared juveniles are shown to survive on the reefs, then a hatchery capable of large-scale juvenile urchin production can be established.

There is little we can do locally to reverse or mitigate the effects of global warming or pollution from far off sources such as the rivers that empty in the Gulf of Mexico or wind blown African dust, but it may well be possible to greatly reduce the algal growth that is smothering our reefs through restoration of the long-spined sea urchin. The value of a successful restoration program can be measured by the value of our coral reefs to the economy of the Keys and South Florida. It may well be that recurrence of the plague or other unknown factors will limit or prevent restoration of *Diadema* to the Keys reefs. The potential for restoration, however, is great enough, and the need for restoration of this herbivore so critical, that to not make a strong attempt to return *Diadema* to our reefs would be inexcusable.